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1. Your reference ~~99 PAT026 / 1283 MCE 99~~ 16 36733

2. Patent application number *(The Patent Office will fill in this part)* **9923199.5** -1 OCT 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

SENTEC LIMITED
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Patents ADP number *(if you know it)* 7353733002

If the applicant is a corporate body, give the country/state of its incorporation UNITED KINGDOM

4. Title of the invention

MAGNETIC DATA TAGS

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

~~SENTEC LTD~~
~~(as above)~~

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Patents ADP number *(if you know it)* 1669004

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
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Number of earlier application	Date of filing *(day / month / year)*
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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
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YES

Magnetic Data Tags

This invention relates to the field of passive magnetic data tags and readers. The invention describes a class of data tag with a plurality of magnetic dipole elements. These dipoles are generally made from a soft magnetic element such as Atalante film (manufactured by IST), or high-permeability amorphous metal-glass wire (e.g. from Unitaka , Japan or Vacuumschmelze, Germany, type 6025, or Allied Signal). Each element may differ in saturated dipole moment (i.e. response amplitude), orientation, bias field, coercivity or location.

The authors have previously described magnetic tagging systems in PCT publication no GB2334183. This describes tags and reader systems primarily intended for tags fabricated from material of low coercivity, with elements at different orientations, in which data is recorded primarily by means of the orientation of the elements with respect to each other.

In application no GB 9919100.9, the authors have recently described a reading system for decoding the types of tags described in this invention.

In this invention the authors present new methods to construct tags that store information by means of elements of differing local bias fields, response amplitudes, coercivities and positions. These are generalisations of tags described in, for example, GB2334183, US 5,204,526 (Fuji Electric Co), US 5,729,201 (IBM Corp) and WO 98/26312 (Flying Null).

These types of tags are interrogated by means of a time varying magnetic field. The system described in PCT GB2334183 uses algorithms to identify individual magnetic elements in a data tag by means of their order of appearance during a spiral magnetic scan. GB 9919100.9 extends this technique to cover a wide general range of magnetic data tags.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 illustrates a 40-bit programmable data tag

Description of Embodiments

Introduction

This class of passive magnetic data tags is composed from one or more magnetically active dipole elements. The primary constraints on data tag construction are:

1. Amount of data (number of bits)
2. Physical size
3. Reading method
4. Programmability

Within these constraints, there are many alternative arrangements that can achieve the same result. This invention describes some embodiments that are particularly favourable, in terms of the tag construction and the complexity of the reading/decoding process. Particularly favourable (simple) embodiments are those in which:

1. More than one property varies between elements (selected from orientation, bias, amplitude, coercivity and location (or presence/absence) (leads to more data)
2. One parameter of the element is used to store the data, whilst another parameter of the element is used to distinguish the element (easy to encode the data)

These embodiments do not represent the ultimate data capacity of the tag. The data capacity can be maximised by using more elements, by varying more properties, and by increasing the resolution of the reading system to distinguish between more states (for example, closer orientations or similar amplitudes). The more complex the tag becomes, the less robust the reading system becomes. In general, if there are n different elements, and m different states for each element, there are m^n different possible states. There are $2n$ ambiguities related to which way up the tag is, and which element is which., leading to $m^n/2n$ possible states. The ultimate achievable data density is around ~100 bits of data.

40-bit Fully-Programmable Tag

This contains a number of elements, each at a different orientation, and each with a different bias field. The orientation is used to identify and distinguish the elements, and the bias state of the element is used to store data. Each element occupies a different position on the tag. No information is stored in the position, coercivity or amplitude.

Each element consists of a $9x9mm^2$ square of Atalante thin film material (manufactured by IST of Zulte, Belgium, part number SPR97017A). This material has an "easy" axis of magnetisation. Directly on top of each element is placed a layer of ferric oxide recording tape, with a coercivity of 24 kA/m, and a film thickness of 10μm. This "hard" magnetic material is anisotropic, and the axis of magnetisation is aligned with the soft material.

The tag consists of 21 elements of this type. The elements are arranged on a square grid with a pitch of 10mm, shown in Figure 1. Each element, 1-21, is rotated to a different angle, as shown in the following list.

Element	Angle
1	0°
2	8°
3	16°
4	24°
5	32°
6	40°
7	48°
8	56°
9	64°
10	72°
11	80°
12	88°
13	96°
14	104°
15	112°
16	120°
17	128°
18	136°
19	144°
20	152°
21	164°

The magnetic recording film can be in one of four states: unmagnetised; magnetised parallel to the nominal direction of the element; magnetised at 180° to the nominal direction of the

element; or magnetised with an AC waveform at a pitch of 1.8mm. This final state has the effect of turning the element "off", i.e. preventing it from generating any response in the interrogation field. Each element therefore has four states, and stores 2 bits of data.

The gaps between elements 20 and 21, and between elements 21, are 12 and 16 degrees respectively. All the other elements are at 8 degrees with respect to their neighbours. In the reader system, these two larger gaps provide a reference mark, so that the elements may be correctly ordered.

The total number of states for the tag is 2x21 = 42 states. The total amount of useful data that can be stored is slightly less: one "bit" of data is lost because there is an ambiguity whereby all the elements are magnetised the other way round. In addition, a number of states are not allowed. These are states in which all the elements are turned off (the extreme case) – more generally states in which elements 1, 20 and 21 are turned off, as this prevents correct identifications of the elements. Thus, a conservative figure for the total amount of useful data that can be stored is 40 bits.

The tag is read in a rotating magnetic field of around 2.5 kA/m. At this interrogation field, magnetising the film moves the position of the transitions by about 1°.

The tag can be made more compact by placing the lower two rows (elements 1-10) on top of the upper two rows (elements 12-21). This is because the elements above each other are orthogonal.

Programming

There are a number of programming methods, starting from a fully demagnetised tag:

1. A gapped "recording head", similar to those used for standard magnetic tape, can be used to magnetise the tape.
2. A small permanent magnet may be used to magnetise the recording film in either direction. AC magnetisation may be achieved using a magnet with alternate north-south magnetisation.
3. The tag may be manufactured initially without recording film. Pre-magnetised film is stuck onto each element as required.

4. All elements may be programmed in parallel, using a multipole ferrite magnet arrangement: each element is magnetised by a separate ferrite element, with separate coil connections. This permits all four states of all 21 elements to be defined.

Increased Data Density

In the embodiment above, the tag stores information by the magnetisation of the bias element above the soft magnetic material. No information is stored in the soft element orientation, amplitude response or coercivity. To increase the data density, one or more of these parameters is varied for each element. GB 9919100.9 describes how these parameters may be read independently, for each soft element.

Alternatively, the same data density may be achieved using fewer magnetic elements. This has many practical advantages. The materials costs of the tag are lower, the tag may be smaller, and the reader system will be able to distinguish more tags in the same volume (anti-collision).

Amplitude: using film elements, each element is made narrower than 9mm (perpendicular to the soft axis). In the simplest case, two widths are allowed – 9mm and 5mm. This codes an extra ~1 bit for each element (in fact there are 7 states instead of four). If the reading system can discriminate more amplitudes, then more information may be stored in amplitude. An upper limit is likely to be 4 amplitude states. The amplitude may be changed by altering the size of the dipole element. Alternatively, the magnetic bias layer may be used to alter the dipole's effective width and length, by recording AC patterns on part of the film. Mechanical damage of the magnetic material may also be used to alter its effective geometry.

Orientation: most of the angular "gaps" between elements are identical. More data is coded by allowing these gaps to be unequal. For example, the gaps in the embodiment above are all 8°. By allowing these to be (for example) 7° or 9°, an extra ~1 bit may be encoded for each element. An upper limit of different states is around 4 states – e.g. 6.5°, 7.5°, 8.5° and 9.5°. The design must retain the "big gap" feature, so that the elements are always read in order. This also means that certain combinations of states (e.g. all with large angles) are not allowed, as the big gap would become too small. This is similar to the data encoding described in publication no GB2334183. The minimum gap between elements must not be so small that the signals from two element overlaps or cannot be distinguished unambiguously. In practice,

this means that fewer elements can be used. For example, using the four states above, the tag would be reduced to 17 elements, coding 28 bits of pre-programmed data (by the orientation) and 32 bits of programmable data (by the bias field).

Coercivity: All the elements in the embodiment above have the same coercivity (near zero - ~10 A/m). By allowing each element to have a coercivity selected from a set (for example a set of two or a set of four), additional information may be encoded by each element. An additional ~2 bits of data may be stored in this way. In practice, the maximum number of elements used is reduced.

In all these cases, the gain in data capacity is less than the maximum number of states added, because certain states are indistinguishable – for example, those in which elements are turned off by the bias field, but have different amplitude, orientation or coercivity. In addition, most of these alterations lead to reduced number of elements in practice.

Other Embodiments

The embodiment described above uses the element orientation to identify the elements from each other. Alternative tag constructions might use coercivity, amplitude response or bias to distinguish between different elements. These become more favourable when the number of elements is limited.

Additional discrimination between elements is possible using the methods described below. The response bandwidth of magnetic materials is a function of its construction, and varies between, for example, film and wire, by around two orders of magnitude. By choosing, for example, four classes of materials, an additional 2 bit of information may be stored on each element.

Other materials-dependent properties include: permeability; maximum cross-bias; Barkhausen percentage response as a function of rate of change of field; resonant frequency of magnetostrictive materials.

Tags may be constructed using intersecting/overlaying elements, to make the tag very compact. A particularly favourable implementation is a tag consisting of a series of layers or wires of varying coercivities, arranged at different angles with respect to each other. If there are four possible coercivity states, and 21 elements, then again around 40-60 bits of data may be stored by this type of tag, depending on the exact encoding method.

CLAIMS

1. A magnetic data tag consisting of a plurality of magnetic dipole elements, in which a combination of more than one of element orientation, coercivity, bias and amplitude response are used to store data and/or distinguish elements.
2. A magnetic data tag according to claim 1 consisting of a grid array of dipoles with magnetic bias elements, arranged at different angles, such that the elements are distinguished by their angles, and the data is stored by the magnetic bias state.
3. A magnetic data tag according to claim 2, in which the coercivity may vary between elements, this variation being used to store additional data.
4. A magnetic data tag according to claim 2, in which the amplitude of the response during interrogation may vary between elements, this variation being used to store additional data.
5. A magnetic data tag according to claim 2, in which both the coercivity and amplitude may vary between elements, this variation being used to store additional data.
6. A magnetic data tag according to claim 1 consisting of a grid array of either single dipoles or pairs of substantially orthogonal dipoles, each dipole having a corresponding magnetic bias element, such that the elements are distinguished by their angles, and the data is stored by the magnetic bias state.
7. A magnetic data tag consisting of one or more magnetic elements, in which a combination of more than one of element orientation, coercivity, bias and amplitude response, response bandwidth, maximum cross-field bias, permeability, Barkhausen response and resonant frequency are used to store data and/or distinguish elements
8. A magnetic data tag according to claim 7, containing a single magnetic element.
9. A magnetic data tag according to claim 7 in which additional information is stored by the orientation of the data tag on the tagged item.
10. A magnetic data tag according to claim 1, consisting of a number of intersecting wires, arranged at different orientations, whose coercivities may be chosen from a set of possible values, in which the relative orientations of the elements are used to identify the elements, and to store data, and the coercivities are used to store further data.

ABSTRACT

This invention describes a magnetic data tag comprising multiple magnetic dipole elements with differing saturated dipole moment, orientation, bias field or coercivity. A magnetic data tag constructed with a plurality of magnetic elements, differing by one or more of these factors, can be used to store data.

Sentec Ltd check box:

Pages of text	:	6
Pages of claims	:	1
Pages of abstract	:	1
Pages of figures	:	1

Initial Application

INVENTION TITLE:

Magnetic Data Tags

FIGURES

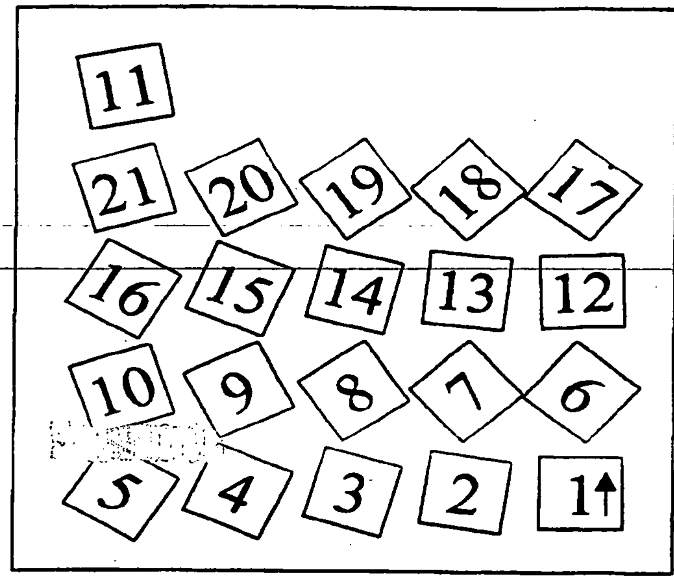

Figure 1

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